

WHAT IS CLAIMED IS:

1. A dual-mode pulse frequency modulation boost converter comprising:
  - a power conversion circuit that receives an input voltage at a first level and that generates an output voltage at a second level, wherein the power conversion circuit includes a switching transistor to generate the output voltage;
  - a pulse frequency modulator configured to control the switching transistor;
  - an inner control loop configured to sense a switching current flowing through the switching transistor and to generate a first feedback signal to the pulse frequency modulator to turn the switching transistor off for a predefined duration when the switching current reaches a predetermined level, wherein the predetermined level is substantially constant in a first mode and is controlled by an output voltage feedback signal in a second mode; and
  - an outer control loop configured to sense a load current, wherein the output control loop turns the pulse frequency modulator off when the load current is greater than a reference level during the first mode and forces the pulse frequency modulator to stay on during the second mode.
2. A dual-mode switching regulator comprising:
  - a switch;
  - a pulse frequency modulator that controls switching cycles of the switch; and
  - a first feedback loop that detects when the switch conducts a current above a selected threshold during each switching cycle and outputs a peak-current detection signal to the pulse frequency modulator in response to turn off the switch for a predefined duration, wherein the selected threshold is a substantially fixed threshold in a first mode and a variable threshold in a second mode.
3. The dual-mode switching regulator of Claim 2, further comprising a second feedback loop that monitors an output of the dual-mode switching regulator for continuous closed-loop regulation and determines whether to operate the dual-mode switching regulator in the first mode or the second mode, wherein the second feedback loop outputs a burst control signal to turn on the pulse frequency modulator for an active period during the second

mode or when the output is less than a first level and to turn off the pulse frequency modulator when the output is greater than a second level.

4. The dual-mode switching regulator of Claim 2, wherein the dual-mode switching regulator is a boost converter further comprising:

an input inductor coupled between an input voltage and the switch;

a rectifying diode coupled between the input inductor and the output of the boost converter; and

a filter capacitor coupled between the output of the boost converter and ground.

5. The dual-mode switching regulator of Claim 3, wherein the second feedback loop provides the variable threshold to the first feedback loop, and the variable threshold is derived from the output of the dual-mode switching regulator.

6. The dual-mode switching regulator of Claim 2, wherein the first mode is a hysteretic mode for relatively light load currents and the second mode is a continuous mode for relatively heavy load currents.

7. The dual-mode switching regulator of Claim 3, wherein the second feedback loop monitors the output voltage of the dual-mode switching regulator.

8. The dual-mode switching regulator of Claim 3, wherein the second feedback loop monitors the peak-current detection signal to switch operation from the first mode to the second mode and monitors the variable threshold to switch operation from the second mode to the first mode.

9. The dual-mode switching regulator of Claim 3, wherein the second feedback loop switches the operation of the dual-mode switching regulator from the first mode to the second mode when the number of switching cycles for the switch exceeds a predetermined value during an active period of the pulse frequency modulator.

10. The dual-mode switching regulator of Claim 3, wherein the second feedback loop switches the operation of the dual-mode switching regulator from the second mode to the first mode when the variable threshold is less than a predefined level.

11. The dual-mode switching regulator of Claim 2, wherein the output of the dual-mode switching regulator drives one or more light emitting diodes.

12. A switching converter comprising:  
a semiconductor switch;  
a pulse frequency modulation controller configured to turn the semiconductor switch on and off;  
a peak current detector configured to sense current flowing through the semiconductor switch and to output a peak current pulse to the pulse frequency modulation controller when the sensed current is above a reference peak level, wherein the pulse frequency modulation controller turns off the semiconductor switch for a predetermined duration in response to the peak current pulse;  
a feedback voltage detector configured to sense an output voltage of the switching converter and to output a control signal to the pulse frequency modulation controller, wherein the control signal is in an active phase and turns on the pulse frequency modulation controller when the sensed output voltage is less than a first predefined voltage, and wherein the control signal is in an inactive phase and turns off the pulse frequency modulation controller when the sensed output voltage is greater than a second predefined voltage; and  
a load sensor configured to detect load current and to output an override control signal to force the pulse frequency modulation controller to remain on when the load current is greater than a predetermined level, wherein the reference peak level of the peak current detector is a variable peak level that varies with the sensed output voltage when the override control signal is active.
13. The switching converter of Claim 12, wherein the reference peak level of the peak current detector is substantially constant when the override control signal is inactive.
14. The switching converter of Claim 12, wherein the variable peak level is generated by a filter circuit coupled to an output of the feedback voltage detector.
15. The switching converter of Claim 14, further comprising a clamp circuit coupled to an output of the filter circuit to set the variable peak level at a predetermined value when the override control signal is inactive.
16. The switching converter of Claim 12, wherein the feedback voltage detector is a first comparator with hysteresis and the sensed output voltage is provided to a negative

input terminal of the first comparator while a first reference voltage is provided to a positive input terminal of the first comparator.

17. The switching converter of Claim 12, wherein the load sensor further comprises:

- a counter that increments with each peak current pulse and resets when the control signal is in the inactive phase; and

- a latch that sets when the counter overflows indicating that the load current is greater than the predetermined level and resets when the variable peak level is less than a predefined level indicating that the load current is less than the predetermined level.

18. The switching converter of Claim 16, wherein the load sensor is a second comparator and the first reference voltage is provided to a positive input terminal of the second comparator while a second reference voltage is provided to a negative input terminal of the second comparator.

19. A method for improving efficiency of a switching regulator that uses pulse frequency modulation to control a switch, the method comprising the steps of:

- turning on a pulse frequency modulator for a burst period when an output of the switching regulator is less than a first level, wherein one or more switching cycles for the switch occur in the burst period;

- turning on the switch in each switching cycle until the switch conducts a peak current followed by a switch off-time of a predetermined duration;

- operating the switching regulator in a hysteretic mode for a first range of load currents, wherein the peak current for the switch is substantially fixed and the pulse frequency modulator turns off when the output of the switching regulator is greater than a second level; and

- operating the switching regulator in a continuous mode for a second range of load currents, wherein the peak current for the switch varies according to a feedback signal indicative of an output of the switching regulator and the pulse frequency modulator is forced on to extend the burst period until the variable peak current is less than a predefined level.

20. The method of Claim 19, wherein the switching regulator switches between operating modes by indirect sensing of the load current.

21. The method of Claim 19, wherein the switching regulator switches from the hysteretic mode to the continuous mode when the number of switching cycles in a burst period exceeds a predetermined value.

22. The method of Claim 19, wherein the switching regulator switches from the continuous mode to the hysteretic mode when the variable peak current is less than the predefined level.

23. A switching regulator using a dual-mode pulse frequency modulation technique comprising:

means for operating in a hysteretic mode, wherein regulation of an output of the switching regulator is performed using a substantially fixed peak switching current; and

means for operating in a continuous mode, wherein regulation of the output of the switching regulator is performed using a variable peak switching current.

24. The switching regulator of Claim 23, further comprising means for sensing load power to switch between the hysteretic mode and the continuous mode.